a very-difficult case, and further aiding in building a baseline case that is overall appropriately more difficult than most field studies will be (in terms of achieving good signal-to-noise ratios and depths of investigation). The field survey consisted of 40 in-loop TEM stations, divided into 3 lines, for 4 line-km of data. The survey was carried out by a crew of one person, with square Tx wire loops 100 m on a side, and a ferrite-core magnetic coil Rx antenna in the center of each Tx loop. Maximum useful depth of investigation achieved was 600 m. For control, there are 4 USGS test wells in the area, that have shown water levels from 116.27 m to 124.68 m. In order to evaluate the best frequency to use for the survey, several test soundings were collected at two locations: Station 50 (first station) on Line 1, and again at Station 650 (seventh station) on Line 2. At Line 1/ Station 50, test soundings were collected at 8 Hz, 16 Hz, and 32 Hz. It is clear from the test data that 16 Hz provides the cleanest data out to the latest decay times. At Line 2/ Station 650, test soundings were collected at 8 Hz and 16 Hz. Again 16 Hz provides the cleanest data out to the latest times. Based on the results from the test soundings at Line 1/ Station 50, 16 Hz was used as the sounding frequency throughout the survey, with the additional test soundings at Line 2/ Station 650 confirming the soundness of this choice. CONCLUSIONS: TEM provides a cost-efficient way of mapping deep groundwater, and can be carried out with very small crews and relatively low-cost equipment. The very conductive subsurface environment and abundance of powerline noise sources in the field area makes this an appropriately difficult environment in which to carry out these continued baseline studies. Data from Lines 1, 2, and 3, all show resistivities in the range of 10 to 100 Sm from the surface down to the water table, consistent with the clay-rich soil in the area. The resistivity gradient seen at 120 m roughly matches the USGS well data.

P53A-06 1330h INVITED POSTER

Data from HEND/Odyssey Show That Northern and Southern Permafrost Regions of Mars Have Different Subsurface Structure

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After the first Martian year of mapping neutron emission by Mars Odyssey the existence of large regions with very strong depression of neutron albedo has been discovered around both poles. The depression is about a factor of 10 for both regions relative to the maximum emission at Solis Planum. The origin of these depressions is explained by the presence of a large amount of ground water ice in the shallow subsurface, about 1-2m. Accordingly, these regions of depressed neutron flux were identified with Northern and Southern permafrost regions on Mars with a very high content of subsurface water ice. Neutrons observed from the Odyssey orbit depend on the thickness of the atmosphere, the current flux of cosmic rays and the composition of subsurface. Additionally, the leakage flux of neutrons is contributed by the entire visible surface of the planet, and neutron mapping data do not provide direct measurements of ground water distribution and stratification of the subsurface. To get this knowledge, one must model the subsurface, consistent with the observations, and perform model-dependent deconvolution of measured neutron counts to estimate water content. It was found that the Northern permafrost region is well described by a simple model of the subsurface with homogeneous distribution of water ice throughout. This model uses soil of fixed composition consistent with APXS observations and a variable content of water over the subsurface. The average content of water ice in the subsurface was estimated as 44, 25 and 13wt% for the northern latitude belts $> 80^\circ$, 70-80° and 60-70°, respectively. For the Southern permafrost region the simple model with homogeneous subsurface distribution of water ice is not supported by observations. The model with double-layered subsurface was proposed for this region, with only 2wt% of water in the top dry layer of variable thickness and with variable content of water in the bottom layer. The double-layered model was found to be consistent with observations for the Southern region. The average content of water ice in the bottom layer was estimated as 55, 54 and 25wt% for the southern latitude belts $> 80^\circ$, 70-80° and 60-70°, respectively. Correspondingly, the average thickness of the top layer is about 16, 19 and 22 g/cm^2 for the same latitude belts $> 80^\circ$, 70-80° and 60-70°, respectively. So, the northern and southern permafrost regions have different subsurface structure. One may suppose that the southern shield of water ice was produced a long time ago, and subsequently the top dry layer was formed by losing water by sublimation into the atmosphere. In contrast, the absence of a dry blanket above the ice bearing material at the northern region suggests that at the present time condensation of water dominates over sublimation into the atmosphere. Thus, in the current climate epoch the surface of the northern permafrost region is being built up by ice and dust deposition from the atmosphere.

P53A-07 1330h POSTER

Monazite in Mafic Dykes from the Bastar Craton, India: Implications for LREE Depletion in Martian Basalts

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Martian basalts (shergottite meteorites) display very large variations in their incompatible element systematics, as evidenced by their highly fractionated and variable whole-rock REE patterns. Some samples show a marked depletion in LREE, which is apparent in CI-normalized bulk rock La/Sm ratios: some samples, such as Shergotty and Zagami, have La/Sm$\sim$0.9, i.e., relatively flat REE patterns; others, such as QUE 94201, have La/Sm$\sim$0.1, reflecting a depletion in LREE relative to the M-HREE. Furthermore, Sm-Nd isotopes in these samples indicate that their source regions are more enriched in LREE relative to M-HREE than the basalts themselves: the ^{147}Sm/^{144}Nd ratios estimated for martian basalt sources (from initial ϵ-Nd^{143}) are 50 to 80% less than the whole-rock ^{147}Sm/^{144}Nd ratios of the basalts (Borg et al. 2001, 2003). This suggests that fractionation of LREE from M-HREE was a relatively recent phenomenon and occurred either in the source region, during magma generation, or during subsequent magma differentiation. This fractionation could reflect the involvement of a LREE-enriched phase in the petrogenesis of the martian basalts. One possibility is that this phase remained in the restite during partial melting, so that the melting process preferentially excluded LREE (Borg et al. 2003). This is supported by modeling of REE partitioning between liquid (=parental melt) and orthopyroxene, olivine and majoritic garnet (Borg and Draper 2003; Draper et al. 2003), which is unable to reproduce the LREE depletions. The phase (or process) responsible for the LREE depletion in the basalts must be able to strongly fractionate La-Nd from Sm-Lu.

Monazite is a LREE-phosphate, generally: (La, Ce, Nd, Th)PO4; it is poor in HREE relative to LREE (Spear and Pyle 2002). Although a common accessory mineral in granites and metapelites (Rapp et al. 1987; Spear and Pyle 2002), to our knowledge, none has previously been reported in basalts.

The Bastar craton of India is transected by multiple generations of mafic dyke swarms, and the emplacement age of one major swarm of tholeiite dykes has now been well established at $\sim$1.9 Ga (French et al. 2004). In searching for minerals suitable for chemical and isotopic dating, a number of late-crystallizing accessory phases were found in these dykes including zircon, baddeleyite, zirconolite, allanite, and monazite. We interpret the monazite to be a primary magmatic phase on the basis of its euhedral morphology, and its occurrence as an inclusion in undoubtedly magmatic clinopyroxene. Furthermore, its Th-U-Pb chemical age is within error of emplacement ages determined for this dyke swarm, indicating that the monazite is not xenocrystic in origin. LREE-oxide concentrations in the monazite are up to 65 wt%, corresponding to $\sim 10^5$ to 10^6X CI for La-Nd and $\sim 10^4$X CI for Sm-Gd. Nd is fractionated from Sm by a factor of 2; La/Sm$\sim$11 and La/Gd$\sim$55. As these enrichments are crystal-chemical in nature (cf. whole-rock REE $\sim$100X CI; La/Sm$\sim$2; Srivastava and Singh 2003), the monazite from the Bastar dykes represents a phase capable of fractionating LREE from M-HREE in mafic systems.

Recognizing that studies of the stability of monazite in mafic systems at mantle pressures are required to test this hypothesis, we speculate that accessory monazite represents a possible candidate for the fractionation of LREE from M-HREE in the martian basalts.

P53A-08 1330h POSTER

Remote Sensing and Electrodynamic Model of Chicxulub Crater

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Advances on space observational systems have opened new exiting possibilities to investigate our planet in an unprecedented detail and in a global scale. Information retrieved from surveys of other solar system bodies like our moon, planets and satellites, from missions like Apollo, have documented the origin of planetary surfaces and the role of impacts as a major process. Voyagers 1 and 2 and Galileo have showed impact craterism is a process rather generalized in all bodies of the solar system. Thus establishing it as part of the major processes to be considered for the evolution of our planet, together with tectonics, mantle process, volcanism, weathering, etc. Investigations on impact craters from solar systems provide valuable information on different surfaces, crustal thickness, existence of crust layers, type of material under the most superficial layer, type of bolide which formed crater, impact angle, etc. The studies constitute an important tool to rebuild the planets geological history and develop theories on their internal structure. The Chicxulub crater in the carbonate platform of the Yucatan peninsula is one of the largest multiring structures found on Earth. The crater is some 180-200 km in diameter, is well preserved and has been studied in the past few years (geophysical surveys and drilling programs). The crater is buried under a thick sequence of tertiary carbonate rocks, and on the surface there are relatively few indications of the crater (e.g., topographic depression, ring of cenotes). In this study, it is analyzed and presented an electrodynamic model for an impact crater and its electrophysical properties, these data are derived from Fisher inverse matrix elements. We also present a surface model for the buried Chicxulub crater derived from remote sensing data.

P53B CC: 220 C-E Friday 1330h

Physicochemical Properties of Planetary Cores III Posters *(joint with T)*

Presiding: **Y Wang,** Advanced Photon Source**; D C Valencia,** Harvard University

P53B-01 1330h POSTER

Rheology of Earth's Inner Core

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Here I use mineral physics constraints to evaluate the viscosity and creep mechanisms of iron at the conditions of the inner core. At low to intermediate stresses and temperatures near the melting point solid materials may deform by any of three mechanisms: power law creep, diffusion creep and Harper-Dorn creep. Both power law and Harper-Dorn creep are dislocation processes, and the transition between the two occurs at a stress level on the order of the Peierls stress, with power law creep dominating at higher stresses. The transition stress is predicted to be $\sim$3 MPa for hcp-Fe at inner core conditions, which is far higher than the stresses of $\sim 10^2$ to 10^3 Pa expected from magnetic or gravitational forces. Harper-Dorn creep dominates diffusion creep above a certain grain size, which is predicted to be $\sim$200 microns for hcp-Fe. At the high temperatures and low stresses of the inner core the grain size is expected to be several orders of magnitude larger than the transition value. Harper-Dorn creep is therefore predicted to be the dominant deformation mechanism in the inner core. Harper-Dorn creep is accomplished by the motion of dislocations and can lead to strong lattice preferred orientation. The viscosity in this regime is Newtonian and is given by μ = (kT)/(ADb) where k is Boltzmann's constant, T is temperature, D is the

self-diffusion coefficient, b is the Burgers vector and A is a dimensionless constant predicted to have a value of $\sim$1.7 x 10^{11} for hcp-Fe. No diffusion data exist for hcp-Fe, but metals with similar structure all have nearly the same self-diffusion coefficient at the same homologous temperature. Assuming an inner core temperature of 5700 K and melting temperature for pure iron of 6200 K, the diffusivity is predicted to be $\sim 4 \times 10^{-13}$ m^2 s^{-1} and the viscosity $\sim 6 \times 10^{13}$ Pa s. The corresponding strain rate for a shear stress of 100 Pa is $\sim 2 \times 10^{-12}$ s^{-1}, implying that large strains are possible on timescales less than 100,000 years. It is therefore likely that the anisotropy in the inner core is the result of lattice preferred orientation developed during active or very recent deformation.

P53B-02 1330h POSTER

Viscosity Estimates for the Earth's Fluid Outer Core Revisited

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Over a decade ago, we reported on viscosity estimates for the Earth's fluid outer core (Lumb & Aldridge, J. Geomag. Geoelectr., 43, 93-110, 1991). At that time, estimates for this fundamental deep-Earth parameter ranged over 14 orders of magnitude. Opposite this range we identified: the prevailing wisdom of dismissing higher estimates as upper bounds and taking lower estimates as reliable; self-consistency amongst estimates based on theoretical and laboratory studies of liquid metals (LM), but ranges in estimates inferred from real-Earth (RE) observations; anomalous bulk viscosities, which owe their existence to multiphase fluids, as a plausible explanation for high-value seismically derived estimates; and LM estimates as representative of the molecular viscosity of the outer core, with RE estimates as eddy or effective viscosity estimates. Although each of these findings has been amplified by others, recent results encourage us to revisit estimates for this important physical parameter. In particular, theoretical (e.g., First Principles Molecular Dynamics simulations) and laboratory (e.g., in situ X ray radiography of diamond-anvil experiments) results for liquid-metal alloys (LMAs) exhibit striking self-consistency for increasingly realistic core compositions. Even when extrapolated to realistic core conditions, these LMA results are still orders of magnitude less than results derived from RE observations. Viscosity estimates from the translational motion and differential rotation of the Earth's inner core now complement those estimates derived from other RE observables. Although these real-Earth estimates based on dissipative processes still range over several orders of magnitude, there is some indication of a systematic variation of viscosity with the timescale of the dissipative process. Confirmation of this systematic variation has significant implications. For example, it may form the basis for positing the Earth's fluid outer core as a thixotropic fluid in the broadest sense - i.e., a fluid whose viscosity is modified when subjected to a disturbance. We report here on these recent results, and this systematic variation, in the context of core-mantle coupling and geodynamo modeling.

P53B-03 1330h POSTER

Interdiffusion of Iron and Nickel at High Pressures

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To better understand diffusion-controlled properties of planetary cores, such as viscosity, knowledge about diffusion in iron alloys at high pressures is necessary. We performed a series of experiments to measure Fe-Ni interdiffusion coefficients in solid alloys using diffusion couples consisting of pure Fe and pure Ni rods. The experiments were performed using a multi-anvil device at pressures up to 23 GPa and temperatures up to 1700 °C. The experiments lasted between 2-6 hours, followed by quenching. An electron microprobe was used to analyze Fe and Ni concentrations perpendicular to the diffusion interface. Diffusion coefficients were calculated as a function of alloy composition using the Boltzmann-Matano method. We found that the diffusion coefficients increase smoothly across the diffusion couple from pure Fe to pure Ni by two orders of magnitude. The diffusion coefficients decrease with an increase in pressure. After combining our data with published Fe-Ni interdiffusion data at lower pressures, we found that the activation volume for diffusion does not remain constant; it appears to decrease with pressure. However, the combined data set is consistent with a homologous temperature scaling. The diffusion coefficients we calculated at 12 and 23 GPa agree with published data at 1 atm and 4 GPa at a constant homologous temperature, T/T_m, where T_m is the melting temperature of the alloy at a given pressure. Our data indicate that a homologous temperature scaling is the most accurate method for extrapolating diffusion coefficients to high pressure. An inner core composed of γ-Fe with 10% Ni, at a homologous temperature, T/T_m of 0.85 is predicted to have an Fe-Ni interdiffusion coefficient of $\sim 6 \times 10^{-15}$ m^2/s.

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